Alexandria Engineering Journal (2016) 55, 1359–1365

HOSTED BY

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

REVIEW

Sustaining the shelf life of fresh food in cold chain – A burden on the environment

Oludaisi Adekomaya [a,*], Tamba Jamiru [a], Rotimi Sadiku [b], Zhongjie Huan [a]

[a] Department of Mechanical Engineering, Faculty of Engineering and Built Environment, Tshwane University of Technology, Pretoria 0001, South Africa
[b] Department of Chemical and Metallurgical Engineering, Faculty of Engineering and Built Environment, Tshwane University of Technology, Pretoria 0001, South Africa

Received 19 December 2015; revised 19 February 2016; accepted 20 March 2016
Available online 29 March 2016

KEYWORDS

Environment;
Cold chain;
Shelf life;
Refrigerated vehicles;
Fresh food

Abstract Energy consumption in cold chains has been predicted to rise significantly in view of the increasing world population. Of critical attention is the increasing number of road transport refrigeration which is highly gaining enormous ground globally. In view of the fact that 40% of all foods require refrigeration, 15% of world fossil fuel energy is used in food transport refrigeration. This concern necessitates this study to examine cold chain system with the emphasis on the impact of energy consumption in sustaining the shelf life of fresh food. As the world continues to battle with the global warming occasioned by emission of carbon dioxide from fossil fuel, this study identifies alternative means of saving energy in food transportation system through minimizing energy consumption in diesel engine driven vapour compression system. Preserving perishable fresh food (mainly vegetable) under sub-zero weather is another debacle the authors envisaged in the quest to reduce fossil fuel consumption. This process requires heating the mechanical refrigeration unit in a reverse-cycle to raise the temperature at 0 °C which may further result in more energy demand. The conclusion drawn from this study could be useful in re-designing food transport system for optimal energy saving.

Contents

* Corresponding author. Tel.: +27 735106113.
E-mail addresses: adekomayao@tut.ac.za, oludaisiyetunde@gmail.com (O. Adekomaya).
Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2016.03.024

1. Introduction

Prolonging shelf life of fresh food is vital in sustenance of perishable raw food items. Preserving food is prevalent in the world today as most homes engage in these practices through refrigeration system [35]. Food transport system is another medium of conveying fresh raw food to a possible distant location and it is expected the transportation channels are kept at low temperature conditions (−4 °C to 4 °C) to prolong shelf life and maintain quality of the products. In view of the importance of food transport refrigeration system, United Nation adopted an inter-governmental Agreement on Transportation of Perishable food stuff (ATP) and this agreement provides a specification on insulated body and equipment [31]. Refrigerated vehicles body walls are insulated against heat transfer from ambient temperature into the cooling chamber and ATP developed a blueprint for insulations and equipment to reduce payload on vehicular engine. This agreement classifies transportation equipment (insulation and body wall) as either normally insulated (where the overall heat transfer coefficient U is equal or less than 0.7 W/m^2 K) or heavily Insulated (in which U coefficient equals to or less than 0.4 W/m^2 K). This agreement appeared to have provided the platform for insulating the body wall and despite this regulation, energy consumption in cold chain is still a global challenge and it is reported to account for 30% of total world energy consumption [23]. In the same vein, Meneghetti and Monti [27] have reported that over 40% of all food require refrigeration and about 15% of the same food are being refrigerated due to energy shortfall. In the study conducted by Glouannec et al. [18], it is reported that there are estimated 4 million food transport vehicles in the world and predicted 2.5% increase in the global road freight transport by 2030. This prediction is catastrophic considering the environmental impact of cold chain in view of its energy consumption and emerging implication.

World leaders are currently faced with the challenge of climate change and every resources are being deplored to mitigate its impact on the environment. Sustaining the nature and the climatic environment is a big task to avoid impending and looming danger. Many researchers [2,28] have predicted that the world may naturally go into oblivion if sustainable and pragmatic steps are not taken to reduce fossil fuel consumption which is widely acknowledged to be the major source of carbon emission. Diesel engine driven vapour compression system accounts for huge fuel drain in transport system. A significant CO_2 emission from the refrigerant leakage has equally been source of concern in food transport system. Tassou et al. [31] have studied diesel engine driven vapour compression refrigeration system and concluded that 40% of the greenhouse gas emission results from vehicle's engine and refrigerant leakage. Multi-drop temperature controlled refrigeration system is reported to consume more energy in food chain due to air infiltration as a result of frequent door opening. Table 1 shows CO_2 emission from vehicle engines using an emissions factor for diesel of 2.668 kg CO_2 per litre. For a 38 ton articulated vehicle class, the CO_2 emission of 58 kg CO_2/pallet-km is recorded while 115 kg CO_2/pallet is reported for multi-drop frozen medium rigid vehicle class. Also, CO_2 emission from refrigerant leakage is also a cause of concern to many environmentalists [26,20]. Based on the above, alternative refrigerant may be the best option for refrigerant R404A which has been criticized to be a major contribution to global warming in view of its incessant leakage which could raise the CO_2 emissions from food transport system up to 40% from the vehicle engine (see Table 2). Finnveden et al. [15] have similarly reported 21% of annual refrigerant leakages which is also in the range predicted by Tassou et al. [31]. This study gives the impact of food preservation system on the environment in view of the energy consumption associated with the process. Energy utilisation is a key to social modernization and efforts must be intensified to adopt best international practices to combat climate change which is now a global monster.

2. Energy consumption in cold chain

Preserving quality of fresh food involves a multi-dimensional chain system in which these foods are refrigerated at a lower temperature condition. Different temperature requirements

Table 1 Potential carbon emission from refrigerated vehicles excluding refrigerant leakage (g CO_2/pallet-km) [31].

Category of vehicle	Room condition or ambient	Single drop (chilled)	Multi-drop (chilled)	Single-drop (frozen and varying temperature condition)	Multi-drop (frozen and varying temperature condition)
Medium size	88	106	109	112	115
Large class	85	102	105	108	111
32 ton articulated vehicles	56	69	70	73	75
38 ton articulated vehicles	51	61	63	65	67

Table 2 Potential carbon emission from refrigerant leakage (g CO_2/pallet-km) [31].

Vehicle class	Refrigerant charge (kg)	Average volume load	Annual leakage rate for R404A (per cent of system charge)					
			5%	10%	15%	20%	25%	30%
Medium size	5.0	5.78	1.7	3.3	5.0	6.7	8.3	10
Large class	6.0	8.69	1.3	2.7	4.0	5.3	6.7	8.0
32 ton articulated vehicles	6.5	11.24	1.1	2.2	2.6	4.5	5.6	6.7
38 ton articulated vehicles	7.0	14.38	0.9	1.9	2.5	3.8	4.7	5.6

Table 3 Temperature requirement of selected fresh food.

Fresh food	Temperature requirement (°C)
Fresh fish (in ice), crustaceans and shellfish (excluding live ones)	+2
Meat and cooked meats pre-packaged for consumer use	+3
Cooked meats other than those which have been salted, smoked, dried or sterilized	+6
Butter and edible fats, including cream to be used for butter making	−14
Deep frozen foods	−18
Fishery products	−18

Table 4 Energy requirement in different sizes of cold stores.

Cold store sizes	Energy requirement (kW h/m^3 year)
10,000	100
1000	200
100	600
10	1500

exist in fresh products and these temperature requirements must be sustained to keep these products alive (Table 3).

In developing countries where there is enormous shortfall in power generation and also lack of technical know-how to explore environmental friendly energy, fossil fuel is highly explored as alternative means of energy. This convectional fuel source has been widely reported [6] as global emission of carbon dioxide which is a major contributor to global warming. Keeping raw food in a cold store is purposely for preserving quality. Table 4 shows specification of energy consumption in cold store.

Fresh food transport system is another cold chain where huge volume of energy is needed to keep raw food in safety condition. Transportation of fresh food through diesel engine driven vapour compression refrigeration system is energy intensive especially in multi-drop system. The study performed by Dincer [11] investigated energy application and its environmental impact. The article noted that environmental impact of energy use will continue to be felt in developing countries as highly developed countries continue to expand their industrialized base in developing countries. Several demographers have envisaged that the world population will hit a record high of 15 billion in 2030 and 60% of these people will reside in developing countries. To further illustrate fossil fuel consumption in cold chain, Tassou et al. [31] embarked on a study to access the performance of refrigerated road vehicles with emphasis on diesel consumption in different classes of vehicle type. The result is shown in Table 5 and further validated by similar position taken by Brown et al. [4] on vapour compression refrigeration system.

3. Environmental burden of vapour compression refrigeration system

Several researchers have reported that developed countries currently emit over 15% of greenhouse gases and it is estimated that the emission is likely to increase in view of continuous population explosion. Third world countries are now faced with this same challenge as industries emerge with little or no regard to environmental standards. Of most concern is the emission of carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO) all resulting from the burning of fossil fuel which is widely reported to be a major contribution to acid rain and air pollution. Preserving food

Table 5 Fossil fuel consumption of food transport. Adopted from Tassou et al. [31].

Food transport by type	Fossil fuel required (miles per gallon)	Fuel required (litres per 100 km)	Estimated distance covered in 2004 (million km)	Total fossil fuel consumed in 2004 (million litres)
Rigid 3.5–7.5t	12.3	23	4410	1000
Rigid 7.5–14t	10.5	31	2072	540
Rigid 14–17t				
Rigid 17–25t	7.4	38.2	2310	880
Rigid over 25t	6.4	44.1	2652	1200
Articulated 3.5–3.3t	7.8	36.2	1351	490

system consumes about 20% world energy and as a result of this action, the earth temperature continues to rise with no end in sight.

Copenhagen conference on climate change has given more impetus to increased global temperature rise which is a pointer to continuous global warming and depletion of ozone layer. World leaders have failed to reach a census agreement on mitigating earth temperature rise at Copenhagen conference in 2009. The accord which gives a clear political road map to constrain carbon emission in short and long term basis failed to provide implementation strategy to effectively monitor member countries. The Copenhagen agreement developed a robust and sustainable approach on which there was for the first time a consensus opinion among several countries. One of the laudable agreement in the conference is to limit the maximum global average temperature rise to no more than two degrees Celsius, subject to further review in 2015. Although, this agreement has been criticized by a lot of researchers, especially in vulnerable countries where the adverse effects of the climate change are more pronounced. Their position was anchored on the premise that 1.5 °C remain the most sustainable earth temperature rise. Also, of critical importance to note in the conference is the unanimous commitment among member countries to reduce overdependence on fossil fuel in energy application. Fossil fuel is believed to be a major contribution to climate change and global warming and the conference agreed to explore renewable energy source as a sustainable alternative.

It has been established in many literatures [16,5] that emissions such as CO, SO, and NO, from diesel engine driven vapour compression refrigeration system contribute to long-range environmental disaster as evidenced in the depletion of ozone layer and resulting in increased water level rises. Although CO_2 and SO_2 emissions have been substantially reduced through improved technological innovations in developed countries, Third world countries continue to suffer from effect of emission of CO and CO_2. China and United States remain the leading emission of greenhouse gas and these emissions continue to impact developing countries negatively. Table 6 shows some of the greenhouse gas emission from fossil fuel energy in 2005 which ranked United States as the highest CO_2 emission followed by the European Union and the China.

Environmental impact of these greenhouse gases is shown in Table 7. The gaseous pollutants are analysed in terms of its potential to precipitate greenhouse effect, ozone layer depletion, acid rain effect and smog. These data are based on publication from the literature as shown in the references cited.

Table 6 GHG emissions from fossil fuel and Agriculture in 2005 [13].

Continent/ Country	CO_2 emission	GHG emission from Agriculture	GHG emission from fossil fuel	Ratio of energy to Agriculture GHG
World	5.8	0.9	4.4	4.9
USA	23.4	1.5	20.4	13.6
EU	10.8	1.0	8.5	8.5
Latin America	5.3	1.8	3.0	1.7
China	5.5	0.9	4.1	4.6
India	1.7	0.4	1.1	2.8
Africa	1.4	0.4	0.8	2.0

Table 7 Impact of emissions (CO, CO_2, CH_4, CFCs) on environment [29].

Emissions from DEVCRS	GHG effect	Ozone depletion	Acid rain precipitation	Smog
CO	z	z	z	z
CO_2	x	x/y	z	z
CH_4	x	x/y	z	z
NO and N_2O	z	x/y	x	x
CFCs	x	x	z	z
SO_2	y	x	z	z
O_3	x	z	z	x

Where, x stands for potential contribution and y indicates negligible influence to the effect under study while z indicates 'may not be a general contributor'. DEVCRS stands for Diesel engine vapour compression refrigeration system.

Table 8 Literature assessment of vehicular engine gaseous emission and its projected growth rate.

Emission	Existing concentration (ppm)	Annual projected growth rate (%)	Contribution to greenhouse effect (%)	Reference
CO_2	345	0.4	70	Wolde-Rufael [36]
CH_4	1.64	1.0	8	Xu et al. [37]
N_2O	0.34	0.2	18	Duan et al. [14]

It is also of interest in many literatures to analyse the role of each of the gaseous emission in terms of their potentials to cause greenhouse effect. Table 8 below presents literature assessment of gaseous emission majorly from diesel engine compression system. CO_2 is projected to be the major contribution of greenhouse gas with the growth rate of 0.4% and existing concentration of 345 ppm. This analysis reveals that sustainable measures need to be taken to contain this predicted growth rate.

4. Preservation of fresh food under low temperature conditions

Preserving fresh food mainly vegetable under sub-zero weather condition is another medium through which energy is being drained in vapour compression refrigeration system [34]. The heating capacity of the refrigeration system is made to operate in reverse cycle when the ambient temperature is noticed at 30 °C while the effective refrigeration capacity of the unit is set at 0 °C. This process is mandatory to sustain green vegetable for almost a month and process is acknowledged in the literature as energy demanding [35,24]. This energy consumption is phenomenon and it is estimated that this process could account for 2% of world energy demand [25].

5. Sustainable technologies to mitigate impact of vapour compression Technology

The principle of vapour compression technology has to, to a larger extent, prolong the shelf life of fresh food and it is

Table 9 Alternative technology to vapour compression system.[4]

Method	Predicted efficiency (%)	Developmental state	Coefficient of performance (%)	Limitation barriers	Sustainability and prospect
Eutectic	30–40	Commercial	40–50%	Already in use	Average
Thermoelectric	20–30	Commercial	10–15%	High	Fair
Thermotunnel	50–80	Experimental	No data	Very high	Average
Thermoacoustic	60–100	Prototype	20%	Medium	Good
Magnetic	60–60	Prototype	20%	Medium	Good
Thermionic	20–30	Experimental	$<10\%$	High	Poor
Vapour compression system	70–80	Commercial	65%	Already in use	

noteworthy to emphasize that this technology is done at the detriment of the nature. The world is currently under serious threat due to climate change and it is predicted that its adverse effect will be more pronounced in the coming years if alternative methods are not sought to tackle the effect of food chain. van Hauwermeiren et al. [33] have reported on the need to reduce food preservation time as the only viable way to reduce its impact on the environment. According to Duan et al. [14], reducing food preservation time could only worsen shelf storage life and farmers are likely to be at the receiving end. They recommended 5% slight reduction in storage with humidity monitoring could reduce refrigeration load by 9.25% which will ultimately reduce total store energy load. Table 9 shows some of the existing alternatives to vapour compression refrigeration system as reported in the literature. Some of these technologies are still at the experimental stage but their potential to compete with vapour compression system is explored and presented as reported in the literatures. All these alternatives seem to be facing development barriers at one stage or the other. In case of eutectic system, it is reported to be suitable for short delivery distance since the tube that contains the eutectic solution (phase change material) still needs to be charged from main power [17]. This is a major drawback to the usage of eutectic system because main power supply may sometimes depend on fossil fuel powered energy system which is a major threat to environmental sustainability. Further analysis of Table 9 shows significant improvement in some of the alternatives presented but a lot still need to be done to raise the theoretical Carnot efficiency of some alternatives to practical performance.

Another possible way to cut back overdependence on diesel engine driven vapour compression system is to explore environmental friendly energy systems [8]. Dagdougui et al. [10] also recommended gradual shift from fossil fuel energy to a cleaner and reliable energy. Biofuel energy was considered by Chiellini and Morelli [8] to be a suitable replacement for fossil fuel. In addition, minimising preservation time could be a more sustainable mean of reducing storage and this could be partly achieved by using railways in transportation of perishable citrus fruits [3].

There are over four million refrigerated road vehicles worldwide [18] and the impact of carbon emission from these vehicles accounts for over 40% of world greenhouse gas [21]. Advanced composite materials could be explored by many manufacturers to reduce the impact of insulated panel on refrigerated vehicle engine. Energy consumption in food transport system could be as a result of the weight of insulated panel which is reported to be a payload on food transport in situation where aluminium sheet is used as the internal and external sheet of the reinforcing panel [19]. Insulated bodies of food transport vehicles conveying perishable foodstuffs are measured by the value of overall coefficient of heat transfer (k-value). Thermal conductivity value (k) of aluminium sheet is over 200 W/m K as reported by Dragano et al. [12] and the influence of ambient temperature is pronounced with higher k value of aluminium sheet [22]. A more sustainable approach is to explore fibre reinforced polymeric composite to replace the internal and external wall sheet of insulated panel. Polymer materials have been reported [7] to have excellent specific strength properties and high modulus [9]. These peculiar properties could be investigated and processed to develop a comparable panel to replace the aluminium sheets. Significant fossil fuel energy could be saved while exploring this process. In the light of the above, many authors [1,38,32] have also affirmed that polymer composite hardly dissipates heat and therefore poor conductor of heat. This lower thermal properties of polymer composite could also reduce interference from ambient temperature into the refrigerated chamber thereby reducing thermal load required from the compressor for the cooling system.

6. Conclusion

In this study, the authors have established the impact of diesel engine driven refrigerated vehicles on the environment and the impact may be critical in the future if sustainable approach is not adopted to minimise energy consumption in food chain. In view of the information and data presented in this research, it appears that world leaders need to be more proactive to avert this imminent catastrophe by developing a road map for energy conservation and mitigation. Fossil fuel energy is not definitely a sustainable energy for the future and its utilization continues to surge despite its damaging effect on the environment. This trend must definitely be checkmated.

The following cogent conclusions are drawn from this study:

- The environmental influence of emission from food transport vehicles is established to account for 40% of global greenhouse effect. The capacity, intensity and environmental influence of these transport systems can be reduced through the use of phase change materials (eutectics).

- Alternative technologies appear not to have performed at optimal level compared to diesel engine driven vapour compression system and the best approach to reduce energy drain in food transport system is replacing the metallic internal and external wall sheet of the insulated panel.
- Renewable energy could be explored as an alternative to fossil fuel energy in which its impact on the environment is virtually negligible as reported in many literatures [30,6].

Acknowledgements

This article is part of an extensive research study for PhD work at Tshwane University of Technology, Pretoria, under the supervision of the co-authors and fully supported by the Nigerian Government under the Tertiary Education Trust Fund (TETFUND) to which much appreciation is accorded. The lead author wishes to equally thank the contribution of the co-authors for the time given to check the initial draft of this manuscript and their thorough and constructive criticism of the manuscript which has improved the manuscript in no small measure.

References

[1] H. Abdellaoui, H. Bensalah, J. Echaabi, R. Bouhfid, A. Qaiss, Fabrication, characterization and modelling of laminated composites based on woven jute fibres reinforced epoxy resin, Mater. Des. 68 (2015) 104–113.
[2] A.S. Aliyu, J.O. Dada, I.K. Adam, Current status and future prospects of renewable energy in Nigeria, Renew. Sustain. Energy Rev. 48 (2015) 336–346.
[3] M. Beccali, M. Cellura, M. Iudicello, M. Mistretta, Life cycle assessment of Italian citrus-based products. Sensitivity analysis and improvement scenarios, J. Environ. Manage. 91 (2010) 1415–1428.
[4] D.R. Brown, T. Stout, J.A. Dirks, N. Fernandez, The prospects of alternatives to vapor compression technology for space cooling and food refrigeration applications, Energy Eng. 109 (2012) 7–20.
[5] J.-M. Burniaux, J. Chateau, Greenhouse gases mitigation potential and economic efficiency of phasing-out fossil fuel subsidies, Int. Econ. 140 (2014) 71–88.
[6] I. Capellán-Pérez, M. Mediavilla, C. de Castro, Ó. Carpintero, L.J. Miguel, Fossil fuel depletion and socio-economic scenarios: an integrated approach, Energy 77 (2014) 641–666.
[7] V. Cecen, I.H. Tavman, M. Kok, Y. Aydogdu, Epoxy-and polyester-based composites reinforced with glass, carbon and aramid fabrics: measurement of heat capacity and thermal conductivity of composites by differential scanning calorimetry, Polym. Compos. 30 (2009) 1299–1311.
[8] F. Chiellini, A. Morelli, Ulvan: A Versatile Platform of Biomaterials from Renewable Resources, INTECH Open Access Publisher, 2011.
[9] F. Chowdhury, M. Hosur, S. Jeelani, Investigations on the thermal and flexural properties of plain weave carbon/epoxy-nanoclay composites by hand-layup technique, J. Mater. Sci. 42 (2007) 2690–2700.
[10] H. Dagdougui, R. Minciardi, A. Ouammi, M. Robba, R. Sacile, Modeling and optimization of a hybrid system for the energy supply of a "Green" building, Energy Convers. Manage. 64 (2012) 351–363.
[11] I. Dincer, Energy and environmental impacts: present and future perspectives, Energy Sources 20 (1998) 427–453.
[12] A. Dragano, S. Rossi, P. Bison, G. Panozzo, Experimental evaluation of the optical absorption coefficient of a sandwich panel for insulated vehicles, Quant. InfraRed Thermogr. J. 6 (2009) 207–223.
[13] V.D. Dragomir, The disclosure of industrial greenhouse gas emissions: a critical assessment of corporate sustainability reports, J. Cleaner Prod. 29–30 (2012) 222–237.
[14] X. Duan, X. Yang, G. Ren, Y. Pang, L. Liu, Y. Liu, Technical Aspects in Freeze Drying of Foods, Drying Technology, 2015.
[15] G. Finnveden, M.Z. Hauschild, T. Ekvall, J. Guinée, R. Heijungs, S. Hellweg, A. Koehler, D. Pennington, S. Suh, Recent developments in life cycle assessment, J. Environ. Manage. 91 (2009) 1–21.
[16] E. Friedrich, C. Trois, Quantification of greenhouse gas emissions from waste management processes for municipalities – a comparative review focusing on Africa, Waste Manage. 31 (2011) 1585–1596.
[17] J. Galos, M. Sutcliffe, D. Cebon, M. Piecyk, P. Greening, Reducing the energy consumption of heavy goods vehicles through the application of lightweight trailers: fleet case studies, Transp. Res. Part D: Transp. Environ. 41 (2015) 40–49.
[18] P. Glouannec, B. Michel, G. Delamarre, Y. Grohens, Experimental and numerical study of heat transfer across insulation wall of a refrigerated integral panel van, Appl. Therm. Eng. 73 (2014) 196–204.
[19] D. Gvozdenac, An unsteady-state method for determining overall coefficient of heat transfer (*k*-value) of insulated bodies at variable external temperatures, Heat Mass Transf. 51 (2015) 171–180.
[20] M.M. Ishola, T. Brandberg, S.A. Sanni, M.J. Taherzadeh, Biofuels in Nigeria: a critical and strategic evaluation, Renewable Energy 55 (2013) 554–560.
[21] S.J. James, C. James, The food cold-chain and climate change, Food Res. Int. 43 (2010) 1944–1956.
[22] Z. Jin, B. Tian, L. Wang, R. Wang, Comparison on thermal conductivity and permeability of granular and consolidated activated carbon for refrigeration, Chin. J. Chem. Eng. 21 (2013) 676–682.
[23] M. Kayfeci, A. Keçebaş, E. Gedik, Determination of optimum insulation thickness of external walls with two different methods in cooling applications, Appl. Therm. Eng. 50 (2013) 217–224.
[24] L. Kitinoja, Use of cold chains for reducing food losses in developing countries, Population 6 (5) (2013) 60.
[25] A. Lal Basediya, D. Samuel, V. Beera, Evaporative cooling system for storage of fruits and vegetables – a review, J. Food Sci. Technol. 50 (2013) 429–442.
[26] I.K. Maji, Does clean energy contributes to economic growth? Evidence from Nigeria, Energy Rep. 1 (2015) 145–150.
[27] A. Meneghetti, L. Monti, Greening the food supply chain: an optimisation model for sustainable design of refrigerated automated warehouses, Int. J. Prod. Res. (2014) 1–21.
[28] S.O. Oyedepo, Towards achieving energy for sustainable development in Nigeria, Renew. Sustain. Energy Rev. 34 (2014) 255–272.
[29] S.M. Rahman, A.N. Khondaker, Mitigation measures to reduce greenhouse gas emissions and enhance carbon capture and storage in Saudi Arabia, Renew. Sustain. Energy Rev. 16 (2012) 2446–2460.
[30] M. Repele, G. Bazbauers, Life cycle assessment of renewable energy alternatives for replacement of natural gas in building material industry, Energy Procedia 72 (2015) 127–134.
[31] S.A. Tassou, G. De-Lille, Y.T. Ge, Food transport refrigeration – approaches to reduce energy consumption and environmental impacts of road transport, Appl. Therm. Eng. 29 (2009) 1467–1477.
[32] J.L. Thomason, L. Yang, Temperature dependence of the interfacial shear strength in glass–fibre epoxy composites, Compos. Sci. Technol. 96 (2014) 7–12.

[33] A. van Hauwermeiren, H. Coene, G. Engelen, E. Mathijs, Energy lifecycle inputs in food systems: a comparison of local versus mainstream cases, J. Environ. Planning Policy Manage. 9 (2007) 31–51.
[34] C. Vigneault, J. Thompson, S. Wu, K.C. Hui, D.I. Leblanc, Transportation of fresh horticultural produce. Postharvest Technologies for Horticultural Crops, vol. 2, pp. 1–24.
[35] L. Vincentnathan, Food rights, food frugality, and climate change, Food Foodways 20 (2012) 76–92.
[36] Y. Wolde-Rufael, Energy consumption and economic growth: the experience of African countries revisited, Energy Econ. 31 (2009) 217–224.
[37] Z. Xu, D.-W. Sun, X.-A. Zeng, D. Liu, H. Pu, Research developments in methods to reduce the carbon footprint of the food system: a review, Crit. Rev. Food Sci. Nutr. 55 (2015) 1270–1286.
[38] Z. Zhao, X. Chen, X. Wang, Deformation behavior of woven glass/epoxy composite substrate under thermo-mechanical loading, Mater. Des. 82 (2015) 130–135.